

This briefing is: **UNCLASSIFIED**

The 557th Weather Wing



2d Weather Squadron (2 WS)
Space Weather
Anomaly Assessment Support

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SpaceWOC Flight Commander



U.S. AIR FORCE

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Overview



- 2 WS Space Weather Mission
- The Space Environment
- Space Weather Anomaly Assessments
 - Spacecraft Impacts
 - Degraded Radio Frequency Signal Path
- Anomaly Assessment Support / Examples
- Anomaly Assessment Challenges



2 WS Space Weather Mission



- **2 WS SpaceWOC:** DOD's only 24/7 space environment observing, analysis, and forecast capability at all 3 Security Enclaves
- **Dissemination:** Air Force Weather Web Services, e-mail, phone
- **Volume:** ~35,000 products per day (~34,500 automated)
- **Manning:** 24/7 Operations (1 shift lead, 1 forecaster, 1 analyst)

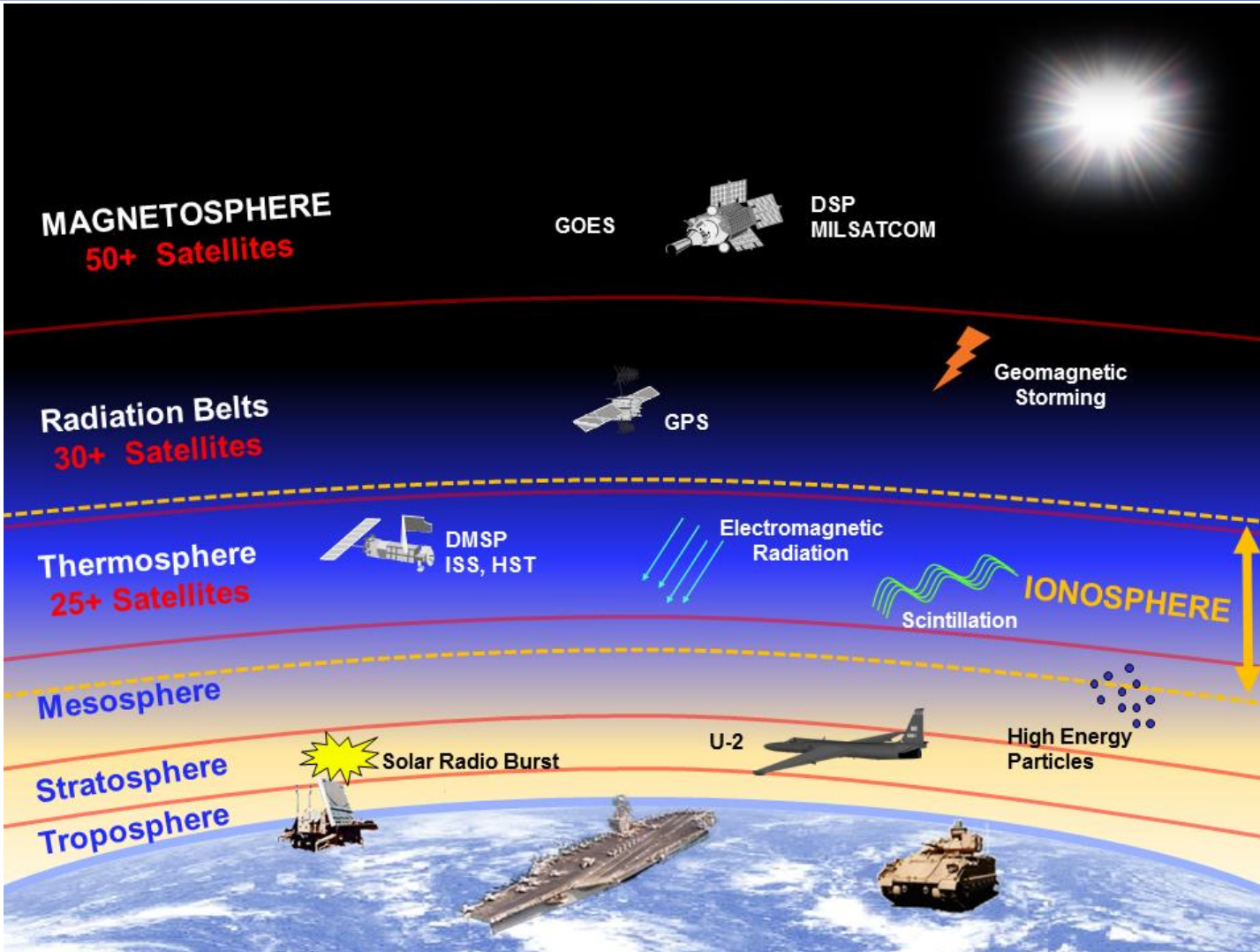


5.2.1. DOC and DOD, in coordination with DHS, will assess best practices across the Federal Government to identify and document the most effective means to produce and deliver space weather alerts, warnings, and notifications.

~NSWAP



Space Environment



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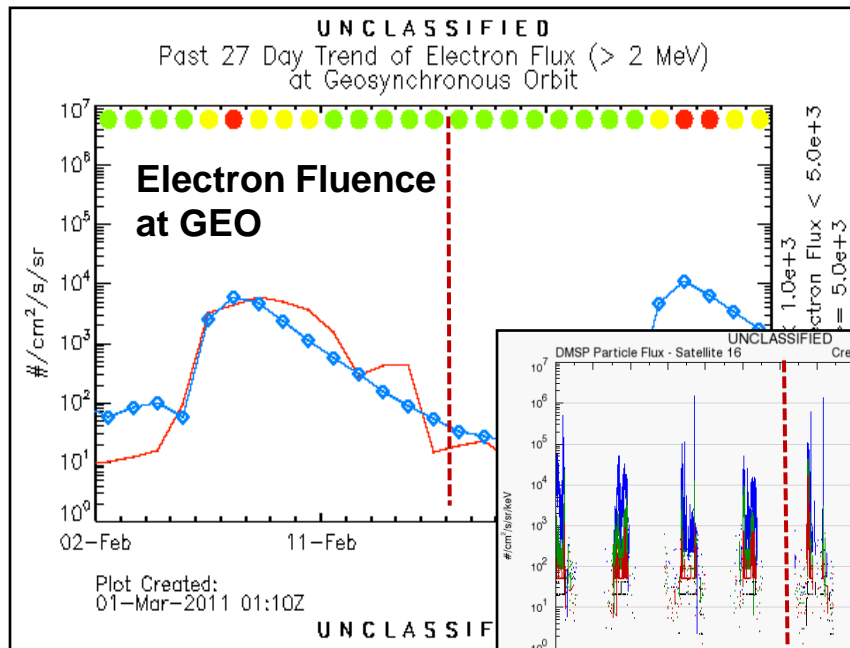
CHOOSE THE WEATHER FOR BATTLE



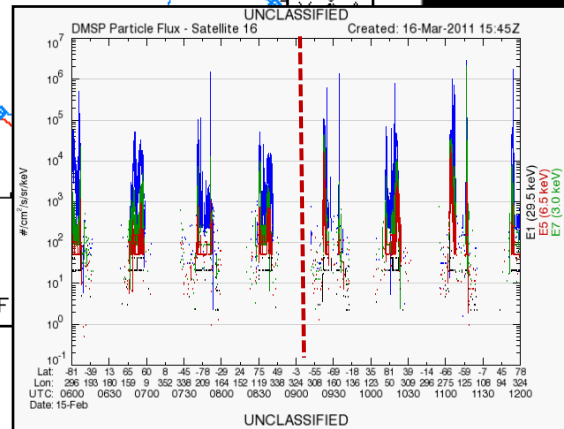
Anomaly Assessments

■ Assessment of Space Weather Environment in support of Spacecraft/Terrestrial Anomaly Resolution

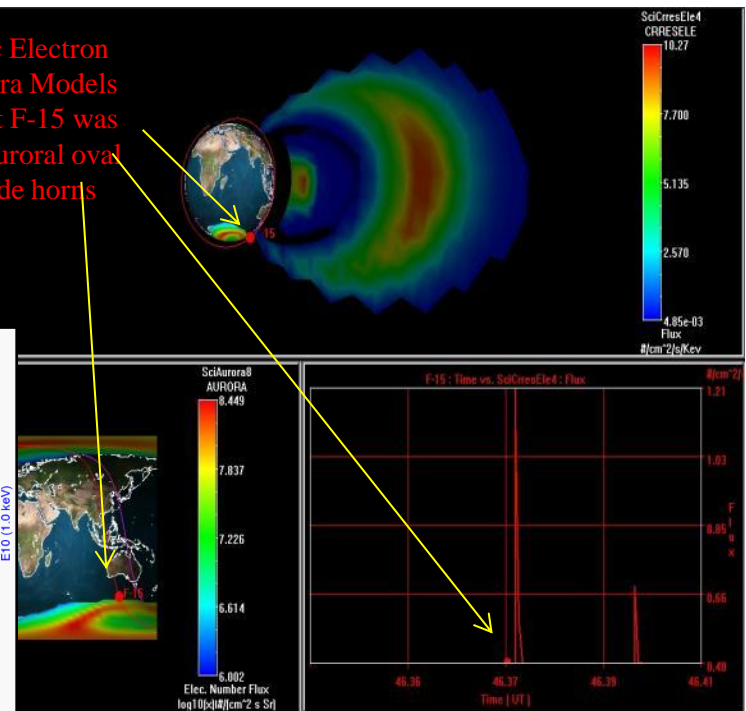
- Real-time Feedback
- Post-event Analysis



DMSP Energetic Particle Flux at LEO



Energetic Electron and Aurora Models show that F-15 was outside auroral oval and outside horns



Global Radiation Belt Model

Metrics: In 2015 2 WS conducted 172 Anomaly Assessments; In 2016, 281 Assessments were conducted.

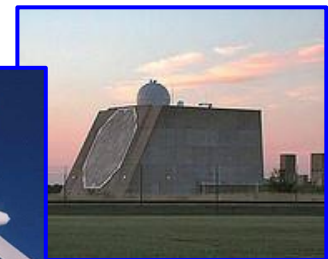
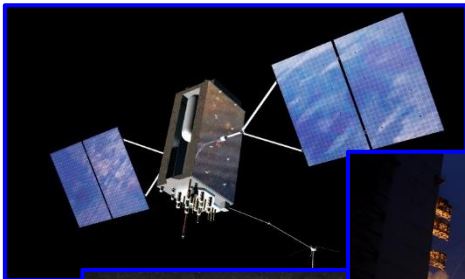


Anomaly Assessments

■ Two Primary Space Weather Anomaly Categories:

■ Spacecraft Impacts

■ Degraded Radio Frequency Signal Path





Spacecraft Impacts



■ Single Event Effects

- Damage to components, electronic shorts, or bit-flips
 - Assessed using GOES proton flux, other ECP sensors, or magnetospheric models

■ Charging (Surface & Internal)

- Electrostatic Discharge
 - Assessed using GOES electron flux, accumulated electron fluence, Van Allen probes, or planetary K-index

■ Total Dose

- Prolonged effects over the course of the system's lifetime

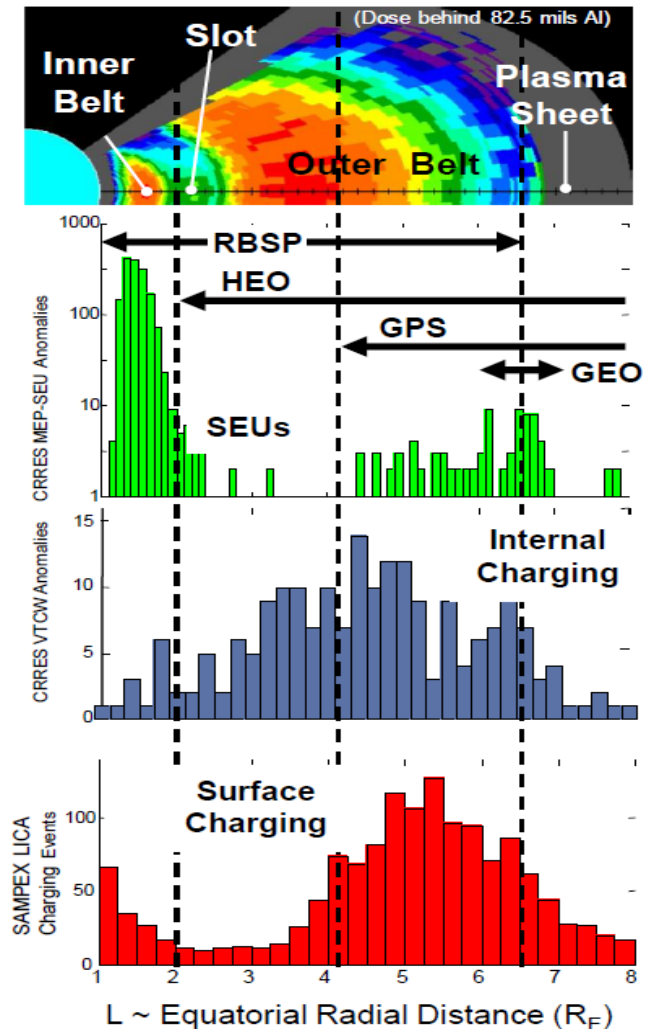
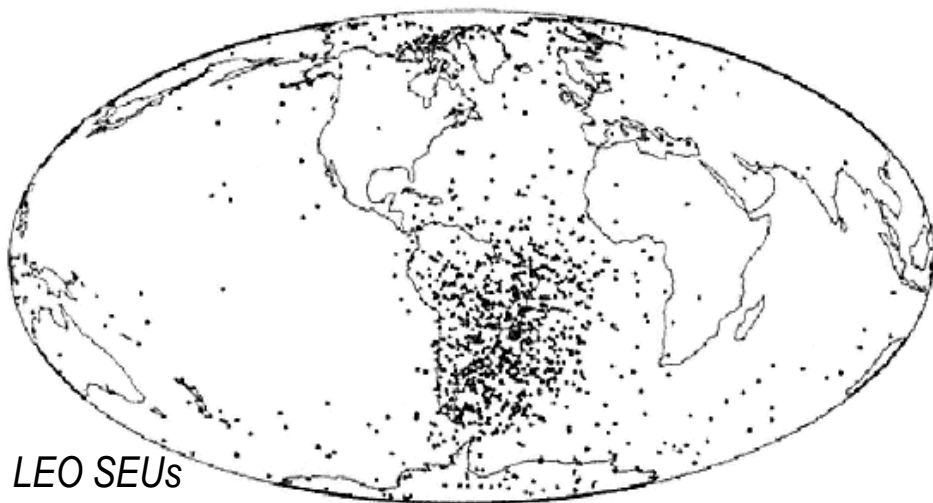


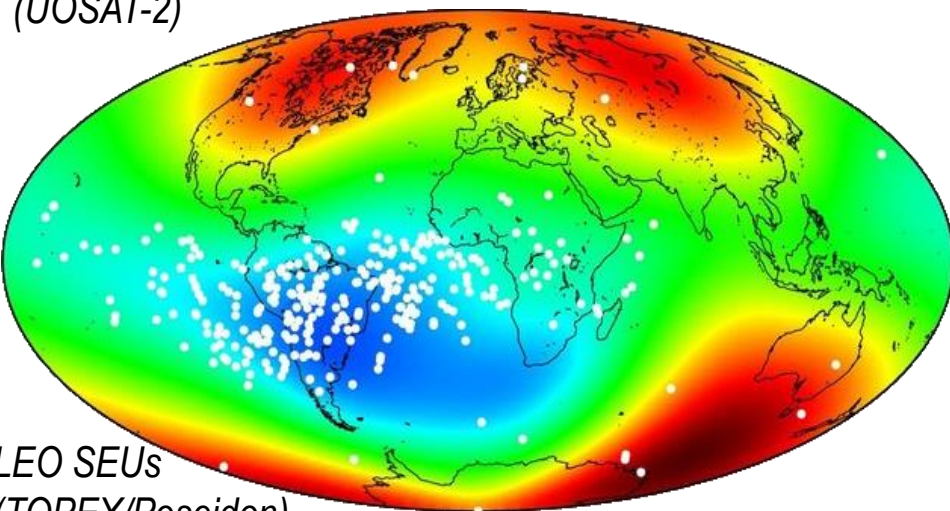
Figure courtesy of Paul O'Brien, The Aerospace Corporation



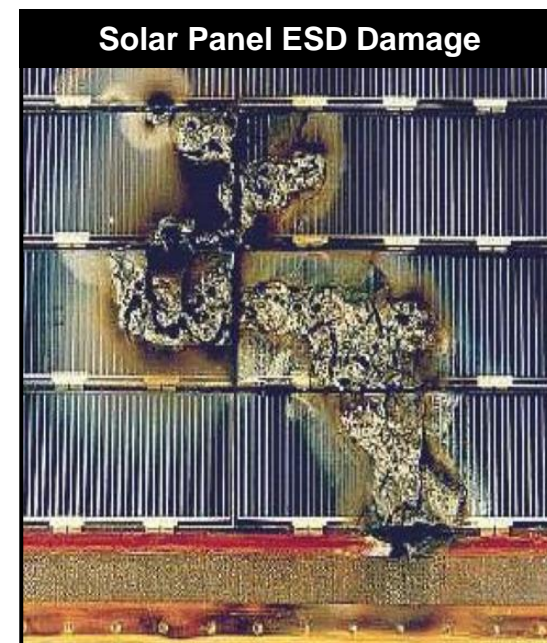
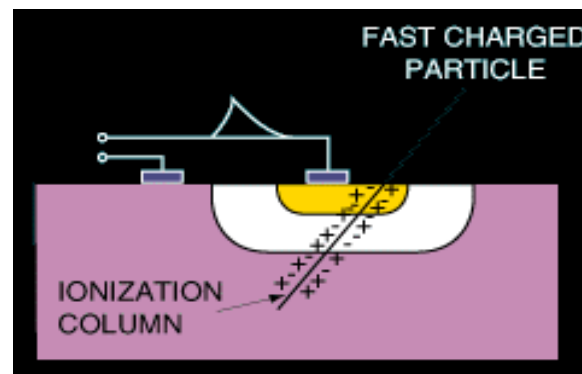
Spacecraft Impacts



LEO SEUs
(UOSAT-2)

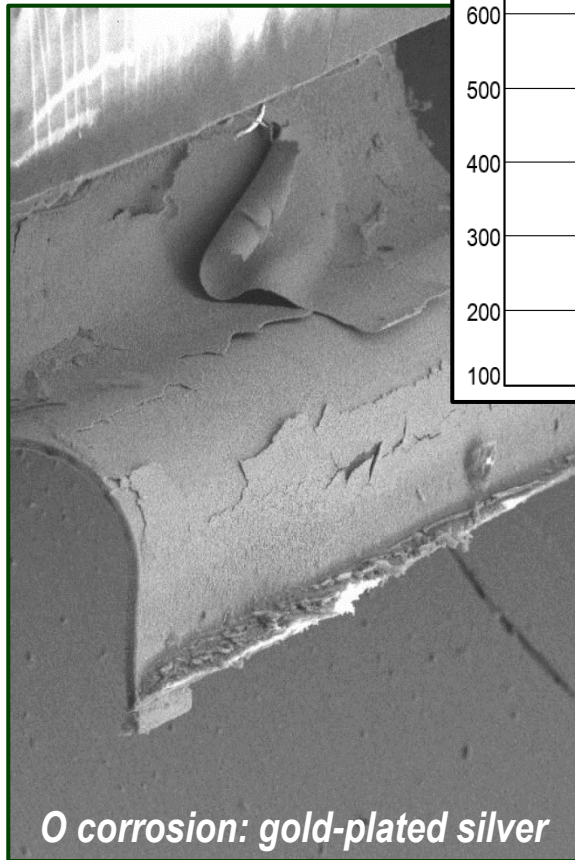
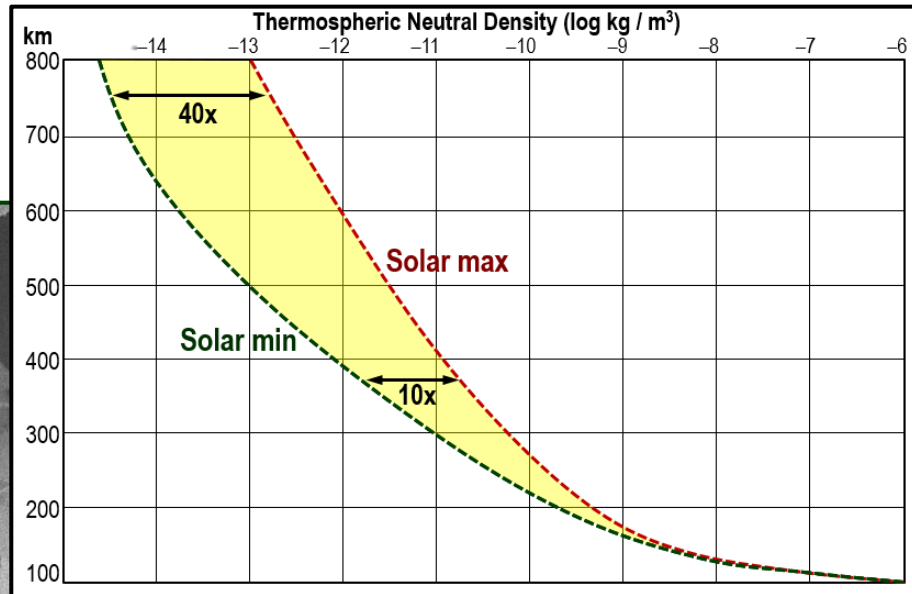


LEO SEUs
(TOPEX/Poseidon)

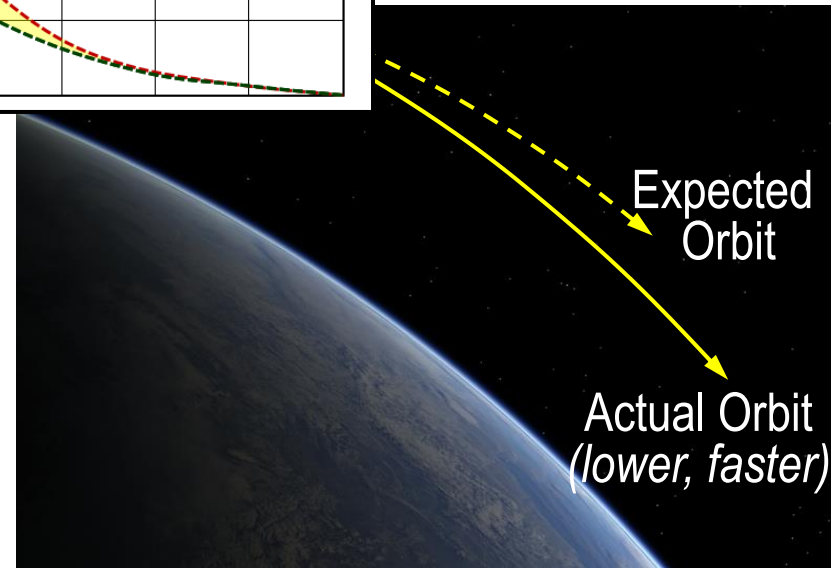




Spacecraft Impacts



0 corrosion: gold-plated silver



Expected Orbit

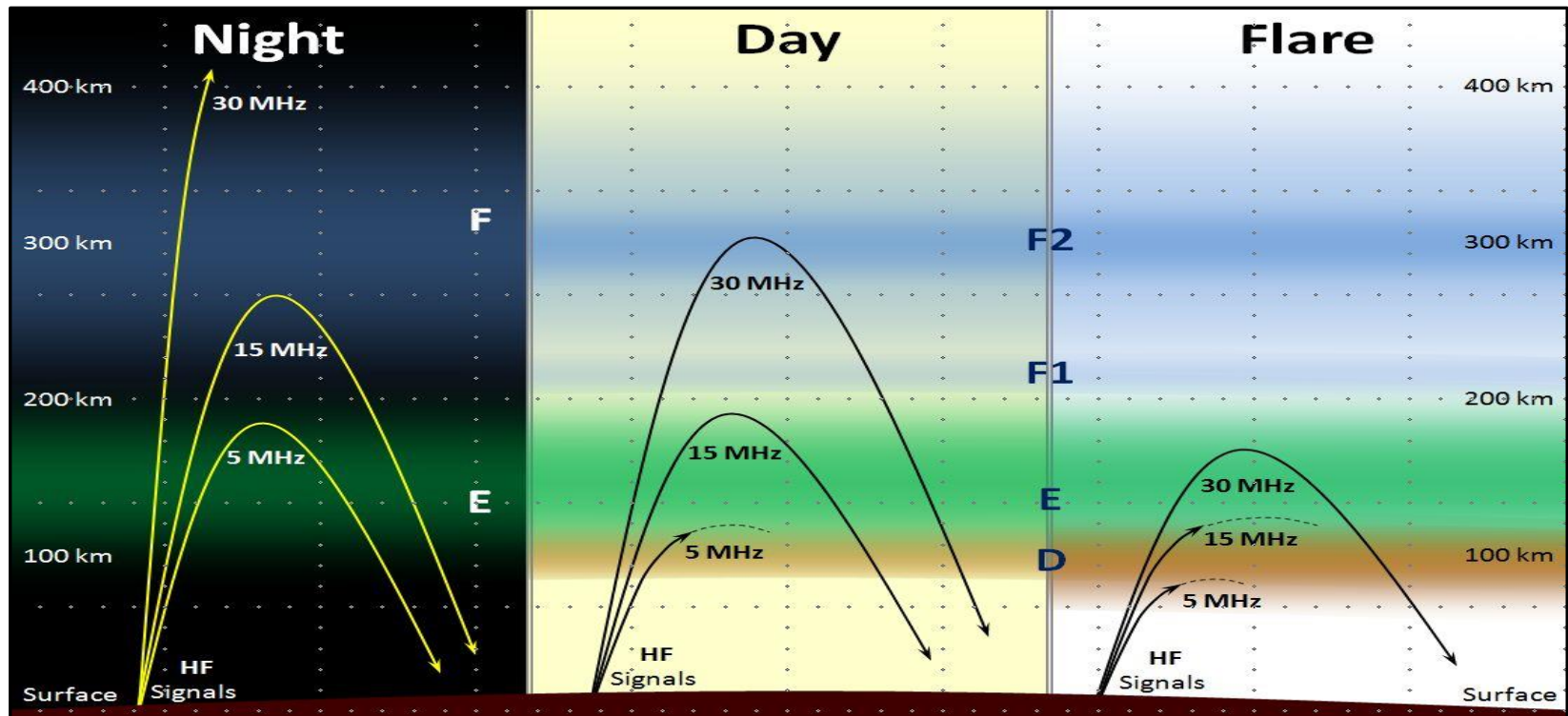
Actual Orbit
(lower, faster)



Degraded RF Signal Path



- High Frequency (HF) radio signals are a common means of communication over the horizon (OTH)
 - Highly dependent on the state of the ionosphere

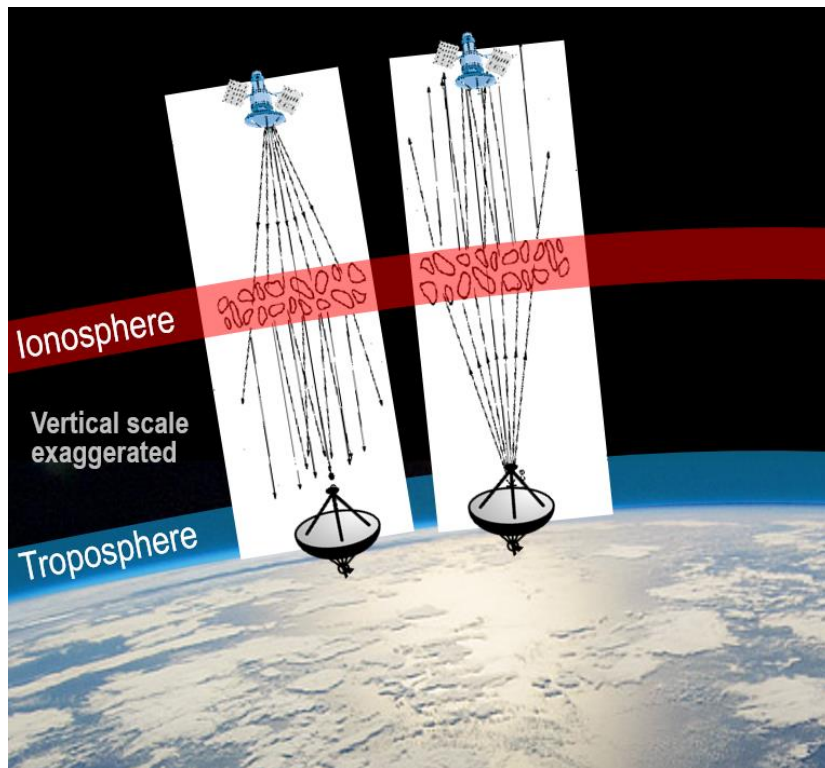




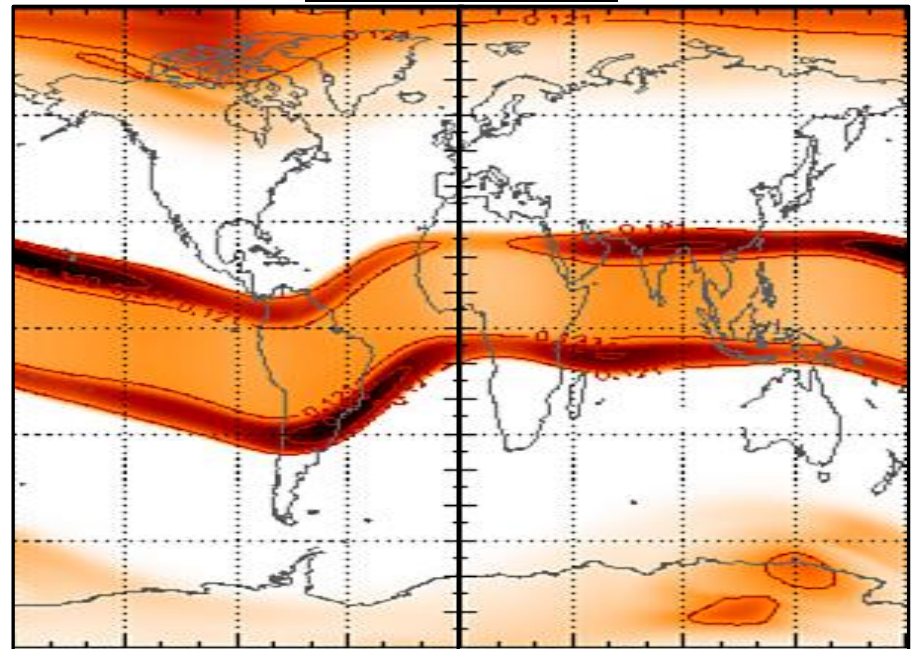
Degraded RF Signal Path



- Ultra High Frequency (UHF) radio signals are commonly utilized for satellite communications (Satcom) & GPS frequencies
 - Greatly modified by an irregular ionosphere



UHF Scintillation





Space Wx Anomaly Assessment Example - GEO



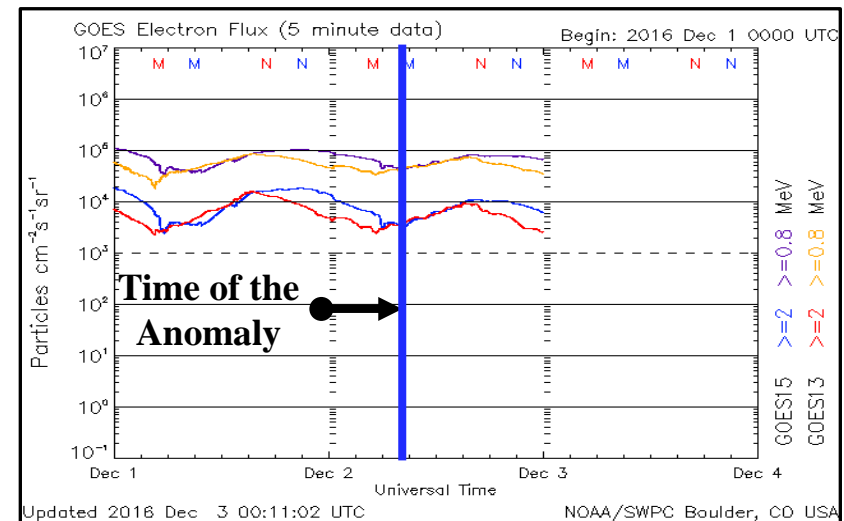
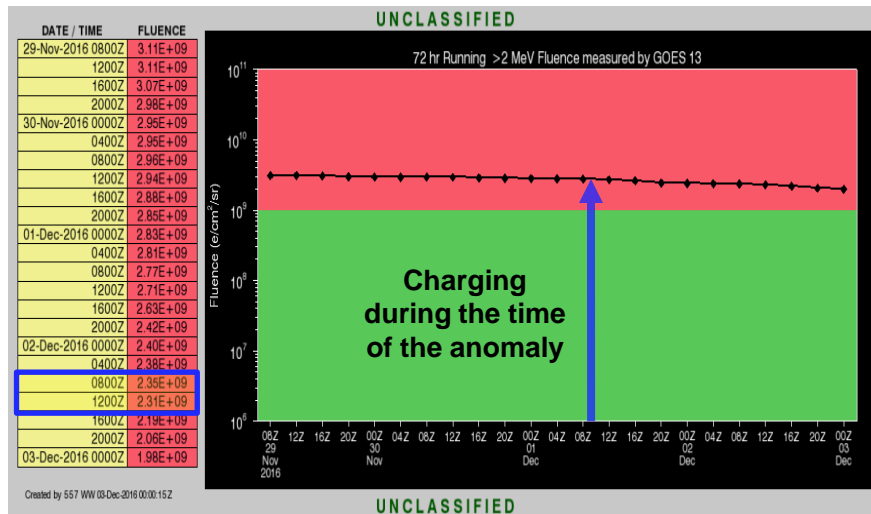
- Report of communications satellite outage on 2 Dec 16 at roughly 0830Z
- Geosynchronous orbit; no other specified orbital parameters or mission descriptions
- Internal Charging is a known hazard at GEO orbits

- Probability – How likely did the space environment contribute to the anomaly?

HIGH MODERATE LOW

- Confidence – How sure are you of your assessment?

HIGH MODERATE LOW





Space Wx Anomaly Assessment Example - GPS



- Two reports of degraded GPS/navigation errors in SW Asia on 22 Oct 16 at roughly 1900Z
- Considerations include internal charging at Medium Earth Orbit (MEO) on GPS satellites and equatorial scintillation effects to UHF signals

- Probability – How likely did the space environment contribute to the anomaly?

HIGH

MODERATE

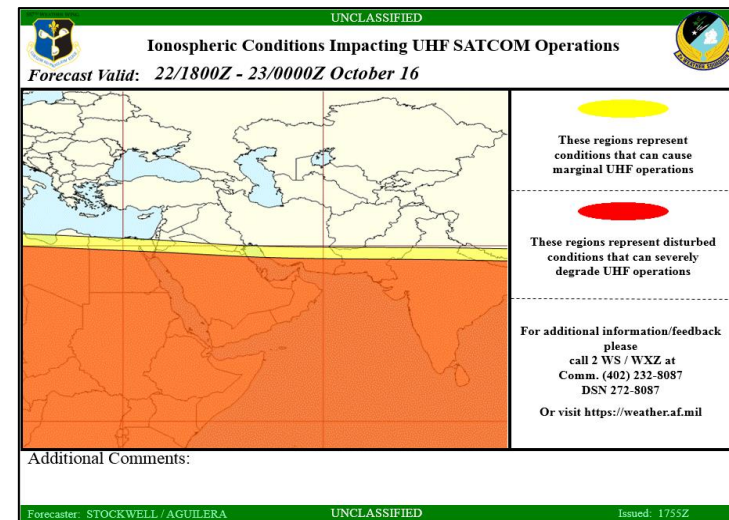
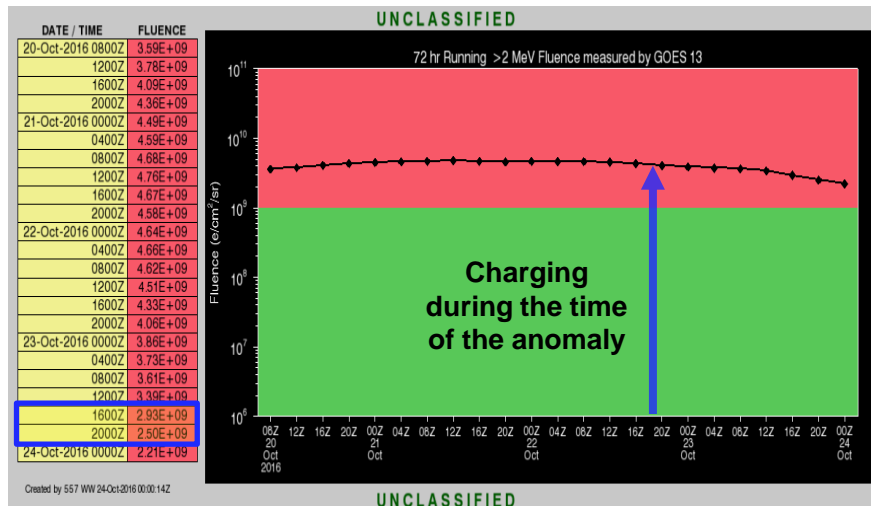
LOW

- Confidence – How sure are you of your assessment?

HIGH

MODERATE

LOW





Challenges

- **Limited Observation Capabilities**
 - Space is a data-sparse environment
 - Sometimes use single point to characterize global phenomena
- **Limited Understanding of Impacts**
 - Some spacecraft impacts well understood
 - More investigation into 2nd and 3rd order effects needed
- **Better Tracking/Archiving of Anomalies & Space Weather Data**
- **Incorporating New Technologies**
 - Automated assessments for spacecraft with ECP sensors
 - Better models for spacecraft without onboard sensors



Summary



- **2 WS Space Weather Anomaly Assessment support is designed to assist the attribution process of our supported users (did space weather contribute to the anomaly?)**
- **Space environmental conditions can cause negative effects/anomalies over the full spectrum of military operations
“From the mud to the Sun”**
- **Space weather anomalies are often categorized as either direct spacecraft impacts or degradation to RF signals**
- **Improved space weather anomaly assessment support is reliant on overcoming several immediate challenges**



Questions?

